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An Introduction to Sage

Arvind S Raj

Department of Cybersecurity Systems and Networks Amrita University, India

1 February 2014 / FOSDEM

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Ougetions

- Graduate CS student at Amrita University, India.
- Passionate about computer security and Python.
- Use Sage in Cryptography labs, Mathematics courses and CTF contests.

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Questions?

Installation

- Pre-built binaries for most OS.
- PPA for Ubuntu.
- Packaging efforts underway for Debian and Fedora.
- GPL licensed mathematics software.
- Unified interface to about 90 popular Python libraries.
- Two modes: command(like Python shell) and notebook(web interface).
- Power of IPython shell and Python programming language.
- "sagerc" file: \$HOME/.sage/init.sage or \$SAGE STARTUP FILE.

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Questions

- Sage interpreter: IPython shell.
- Sage scripts
 - Similar to Python scripts; .sage extension.
 - import names from sage.all
 - Run as sage <filename> <arguments> like Python.
 - Other possibilities: profiling, compiling sage files(Cython), access C functions directly.

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Questions?

- General arithmetic supported by an (I)Python shell.
 - ^ is exponent and ^^ is XOR.
 - For integers, / reduces to lowest fraction and // performs integer division.
- Support mathematical functions and constants with arbitrary precision.
 - pi.n(digits=20) = 3.1415926535897932385
 - e.n(digits=25) = 2.718281828459045235360287
 - golden_ratio.n(prec=60) = 1.6180339887498948
 - $n(\sin(pi/3), prec=60) = 0.86602540378443865$
 - sqrt (263) .n (digits=20) = 16.217274740226854774
 - n(cos(5*pi/4), prec=60) = -0.70710678118654752

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Questions?

· Factorizing polynomials.

•
$$factor(x^4 - 15x^3 + 84x^2 - 208x + 192) = (x - 3)(x - 4)^3$$

•
$$factor(x^3 - 6x^2 + 11x - 6) = (x - 1)(x - 2)(x - 3)$$

- Solving polynomial equations.
 - $solve([x^2 4x + 2 == -1], x) = [x = 3, x = 1]$
 - Solutions to $x^2 + 3xy + y^2 = 0$ and x y = 4 = [[1.1055728, -2.8944272], [2.8944272, -1.1055728]]
- Use find_root where solve does not work. Also useful to find solutions in a particular interval.
 - solve(cos(t) == sin(t), t) = [sin(t) = cos(t)]
 - $find_root(cos(t) == sin(t), 0, pi) = 0.785398163397$

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Questions

- Modulus: mod(27, 12) = 3 and power_mod(27, 2, 12) =
- Primality test: *is_prime*(13) = True, *is_prime*(15) = False
- prime_range(1,35) = [2,3,5,7,11,13,17,19,23,29,31].
 - Generator version: primes(1,35)
- primes_first_n(11) = [2,3,5,7,11,13,17,19,23,29,31]
- next_prime(29) = 31 and previous_prime = 23
- factorial(20) = 2432902008176640000, factor(20) = 2² · 5, divisors(20) = [1, 2, 4, 5, 10, 20]
- gcd(10, 15) = 5, lcm(10, 15) = 30

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Questions⁴

Differentiation

- diff(sin(x) + cos(x) = cos(x) sin(x)
- $diff((sin(x^2)^3)) = 6 x cos(x^2) sin(x^2)^2$
- Integration
 - integral(cos(x) sin(x)) = cos(x) + sin(x)
 - $integral(6 * x * cos(x^2) * sin(x^2)^2, x) = sin(x^2)^3$
- Partial differential and solving differential equations also possible!

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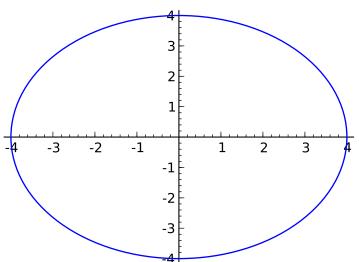
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Questions

Circle of radius 4 centered at (0, 0): c = circle((0, 0), 4)



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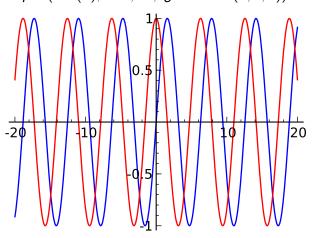
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Questions

Multiple functions in same plot.

$$plot(sin(x), -20, 20, rgbcolor = (0, 0, 1)) + plot(cos(x), -20, 20, rgbcolor = (1, 0, 0))$$



Graph Plotting(cont.)

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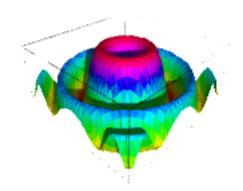
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Questions'

$$f = \frac{\sin(y*y+x*x)}{\sqrt{(x*x+y*y+.0001)}}: plot3d(f, (-3,3), (-3,3))$$



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Questions?

• Creating matrices: m = Matrix([[1, 2], [3, 4], [5, 6]])

Arithmetic operations

•
$$P = Matrix([[1,2],[3,4]]), Q = Matrix([[7,8],[5,6]])$$

•
$$P + Q = \begin{pmatrix} 8 & 10 \\ 8 & 10 \end{pmatrix}$$
, $P - Q = \begin{pmatrix} -6 & -6 \\ -2 & -2 \end{pmatrix}$

•
$$P * Q = \begin{pmatrix} 17 & 20 \\ 41 & 48 \end{pmatrix}$$
, $4 * P = \begin{pmatrix} 4 & 8 \\ 12 & 16 \end{pmatrix}$

•
$$P^3 = \begin{pmatrix} 37 & 54 \\ 81 & 118 \end{pmatrix}$$
, $P^{-1} = \begin{pmatrix} -2 & 1 \\ \frac{3}{2} & -\frac{1}{2} \end{pmatrix}$, $|P| = -2$

 More functions: is_singular, is_symmetric, is skew symmetric, is invertible, is square

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LATEXrepresentation: latex(P)

```
\left(\begin{array}{rr}
1 & 2 \\
3 & 4
\end{array}\right)
```

- view(P): Display PDF(pdflatex)/HTML(MathJAX) depending on mode.
- SageT_EX: Call Sage commands from L^AT_EX.
 - Regular statement: \sage{pow_mod(27, 2, 12)}
 - Plots: \sageplot{plot(sin(x) + cos(x), -20, 20)}
 - \sageblock and \sagesilent: Embedding Sage code

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Questions'

- Interfacing with other algebra systems(GP/PARI, Singular, Maxima)
- Polynomials
- Combinatorics
- Graph and group theory
- Linear algebra
- Elliptic curves
- Advanced portions of everything discussed

References and further reading

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Questions

- Sage tutorial: http://www.sagemath.org/doc/tutorial/index.html
- Thematic tutorials: http://www.sagemath.org/doc/thematic_tutorials/index.html
- Tutorials for those with some mathematics background: http://www.sagemath.org/doc/prep/index.html

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Questions

- · Packaging for Linux distros.
- Improve startup time.
- UI enhancements: Notebook and 2D plots.
- Mobile applications: Android, iOS.
- Mathematicians help with specific libraries.
- Visit http://www.sagemath.org/development.html for more information on getting involved.

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Questions?

Thank you!